345.3

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION
BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

Project

Date November 20, 1950 Author James W. Butcher

SUBJECT—

TITLE

PROGRESS REPORT

STUDIES OF THE BIOLOGY AND CONTROL OF THE LARCH SAWFLY IN NORTHERN MINNESOTA - 1949

By

JAMES W. BUTCHER

FOREST INSECT LABORATORY
MILWAUKEE 3, WISCONSIN

INDEX NO.—

U. S. GOVERNMENT PRINTING OFFICE 16—47272-1

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION
BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE
Division of Forest Insect Investigations

PROGRESS REPORT

STUDIES ON THE BIOLOGY AND CONTROL OF THE LARCH SAWFLY IN NORTHERN MINNESOTA - 1949

By

JAMES W. BUTCHER

FOREST INSECT LABORATORY

MILWAUKEE 3, WISCONSIN

TABLE OF CONTENTS

	TITLE	PAGE NO.
I.	SUMMARY	1
II.	INTRODUCTION	1
III.	SURVEY OF LARCH SAWFLY DAMAGE - CHIPPEWA AND SUPERIOR NATIONAL FORESTS	2
IV.	RELATIONSHIP OF SITE TO SAWFLY ABUNDANCE	5
V.	PARASITE REARING	8
VI.	EXPERIMENTAL CONTROL WORK	10
	A. EVALUATION OF SAMPLING RESULTS	12
	B. PROPOSED PARASITE RELEASE	20
VII.	FRASS SAMPLING AND INTERPRETATION	20
VIII.	LABORATORY STUDIES	23
	A. EFFECT OF PHYSICAL FACTORS ON LARVAL DEVELOPMENT	23
	B. EFFECT OF STARVATION ON LARVAL SURVIVAL	25
IX.	MISCELLANEOUS ACTIVITIES	27
X.	REFERENCES	28
XI.	APPENDIX	29

DEFOLIATION OF TAMARACK BY THE LARCH SAWFLY
PRISTIPHORA ERICHSONII (HTG.)

PHOTOGRAPH "A"
(Average defoliation - 25 percent)

PHOTOGRAPH "B"
(Average defoliation - 100 percent)

PROGRESS REPORT

STUDIES ON THE BIOLOGY AND CONTROL OF THE LARCH SAWFLY IN NORTHERN MINNESOTA - 1949

SUMMARY

Depredations of varying degree by the larch sawfly (Pristiphora erichsonii (Htg.)), have become general over an area of approximately 15,000,000 acres in northern Minnesota during the past 3 years. Assignment of personnel to assess the magnitude of this build-up took place for the first time in late June of 1949. Surveys constituted most of the first year's activities, with experimental control and ecological studies relegated to a secondary role in the work schedule. Results of the surveys made in 1949 are reported elsewhere (Butcher and Eaton 1950) whereas this paper purports to cover activities of a research nature.

Peculiarities of the infestation pattern prompted incipient investigations into the effects of site upon sawfly abundance. By ascribing each stand to a stage in a typical hydrosere, the pattern becomes more explicable; largely because of evidence that water can be an important limiting factor to population build-up. Most of the anomalous situations so far encountered lend themselves to rationalisation from this premise but additional investigation is necessary to ascertain its utility as a working hypothesis.

Analysis of cocoon collections demonstrate that parasitism is a very minor deterrent to population build-up at the present time, averaging less than 2 percent sawfly parasitism by Mesoleius sulicus Grav., and 3.6 percent by Lessa harveyi T. T. for the 26 areas sampled.

Experimental application of DDT in oil at the rate of 1 pound/ gallon/ acre demonstrate the susceptibility of the exposed larvae to this toxicant. However, very real problems of accessibility derive from the prolonged adult emergence period and the scattered distribution of tamarack in general. Much work needs to be done from the standpoint of timing, assessment of stand values and establishment of priorities before this type of control can be recommended unequivocally.

Biological studies were confined to perfecting experimental technique. These are reported as a matter of record. Of these studies might be mentioned the employment of frass sampling as an indicator of biological phenomena. As a result of this work it is possible to predict a drastic decline in populations in one study area on the basis of premature exhaustion of the food supply, with subsequent heavy mortality by drowning due to forced larval drop at the time of heavy flooding. In other, less heavily infested stands, such intra-specific pressure was not operative and dropping was deferred past the period of flooding. As a consequence, survival was greater in the latter area.

INTRODUCTION

The larch sawfly, Pristiphora erichsonii (Htg.), now presents a problem of regional importance for the first time since the early twenties.

As late as 1946, correspondence from the Chequamegon, Ottawa, Nicolet, Chippewa, Superior and Lower Michigan National Forests specifically state that there were no infestations of consequence on those forests at that time. In September of 1946, however, A. C. Hodson of the University of Minnesota (correspondence) called attention to the marked build-up of this insect over northern Minnesota; published acknowledgement following in 1947 (Hodson, A. C. 1947). This report was given tacit confirmation by the participation of personnel from this office, the U. S. Forest Service, and the State of Minnesota in a cooperative larch sawfly spraying project in 1948. It was not until 1949 that personnel became available for assignment to the larch sawfly project in a survey and research capacity.

Authorization for work on this project was delayed in 1949, and, as a consequence, field activities were initiated subsequent to heavy oviposition. Upon arrival at the Cass Lake field station on June 21, it was observed that fifth instar larvae were present although, for the most part, the insect was present in the egg stage. It became evident that the major objective would have to be one of assessing the scope of the infestation with an eye to application of control measures in 1950. As a consequence, emphasis was placed on surveying the infestations both on the Superior and Chippewa National Forests. Biological and ecological studies were undertaken wherever possible but necessarily occupied a secondary role in the first season's activities.

A field aide, James C. Taylor, provided full time assistance with this work. The Forest Service contributed two additional field aides, John F. Nelson and Stanley Gruetzman, who assisted with the cocoon collections for a two-week period. The cost of aerial spraying was financed by the Forest Service and generous assistance was provided by the Chippewa National Forest headquarters staff and field men. This office is also indebted to the Division of Entomology, University of Minnesota, for extending the use of facilities used in parasite rearing, and to Dr. A. C. Hodson in particular for his contributions and further help in establishing contacts with State foresters.

SURVEY OF LARCH SAWFLY DAMAGE - CHIPPEWA AND SUPERIOR NATIONAL FORESTS

Aerial reconnaissance for the larch sawfly on both the Chippewa and Superior National Forests is the subject of an administrative report prepared by Butcher and Leton (1950). A brief historical review of the resurgence of this pest is presented therein, citing very light infestations in 1940, more common occurrence in 1941, and an apparent diminution through 1943 in the Lake States. In 1944-45 heavy defoliation was observed at Pencer, and a general increase was noted at many points on the Chippewa. By 1947, moderate to heavy infestations were described on the Chippewa and Superior, as well as other points outside the National Forests.

Aerial reconnaissance made in July 1949, as described in the above mentioned report, disclosed the general nature of the infestation, but at the same time showed it to be spotty. On the Chippewa particularly, where extensive tracts of tamarack are present, much of it apparently in an unthrifty state, only the fringes showed evidence of injury last year.

In many of the larger bogs on the Superior this same situation prevailed, although in general the more rolling terrain on much of this Forest favors growth of smaller stands; a high percentage of which were severely defoliated in 1949. Smaller stands on the Chippewa also showed heavy defoliation, generally speaking. An attempted explanation of this is offered later in this report.

For the most part it was impossible to visit on foot areas of heavy defoliation observed from the air. Wherever possible, an effort was made to confirm the aerial picture by ground observations. Where this was done on the Chippewa, results indicated that a reasonably accurate picture could be obtained from aerial spotting alone. Since the interior of many bogs is inaccessible to ground travel, experience has shown that evaluation based upon study of a local area can be misleading; a consequence of the marked zonation present in some swamps, and the homogeneous character of others. The former situation prevails in extensive low-lying swamps where all stages of the hydrosere, up to and including tamarack, are still present. Figure 1 illustrates this type of zonation diagrammatically, and for the moment it is only necessary to point out that a fortuitous sampling at zone "C" will not give the same impression of insect abundance as will samplings made at zones "D" or "E". Aerial reconnaissance enables the observer to appraise the over-all picture and the true character of the area is readily apparent. In addition, this type of survey has other advantages where this problem is concerned. It is quickly made and large areas can be covered while the criterion of abundance (defoliation) is most prominent. Aerial reconnaissance is relatively inexpensive, in that large acreages can be traversed with little manpower. Some idea of the ease with which heavy defoliation is recognizable from the air might be gained from reference to Photograph "C" which shows a band of heavily defoliated pure tamarack in striking contrast to the undefoliated spruce component.

PHOTOGRAPH "C"

Panoramic view showing heavily defoliated tamarack (light band) and undefoliated spruce component. (Ely, Minnesota - 1949).

FIGURE 1

DIAGRAMMATIC ILLUSTRATION OF CONCENTRIC ZONATION IN TAMARACK BOG

A- open water
B- ground plants only
C- unthrifty tamarack
D- thrifty tamarack
E- tamarack-spruce-cedar

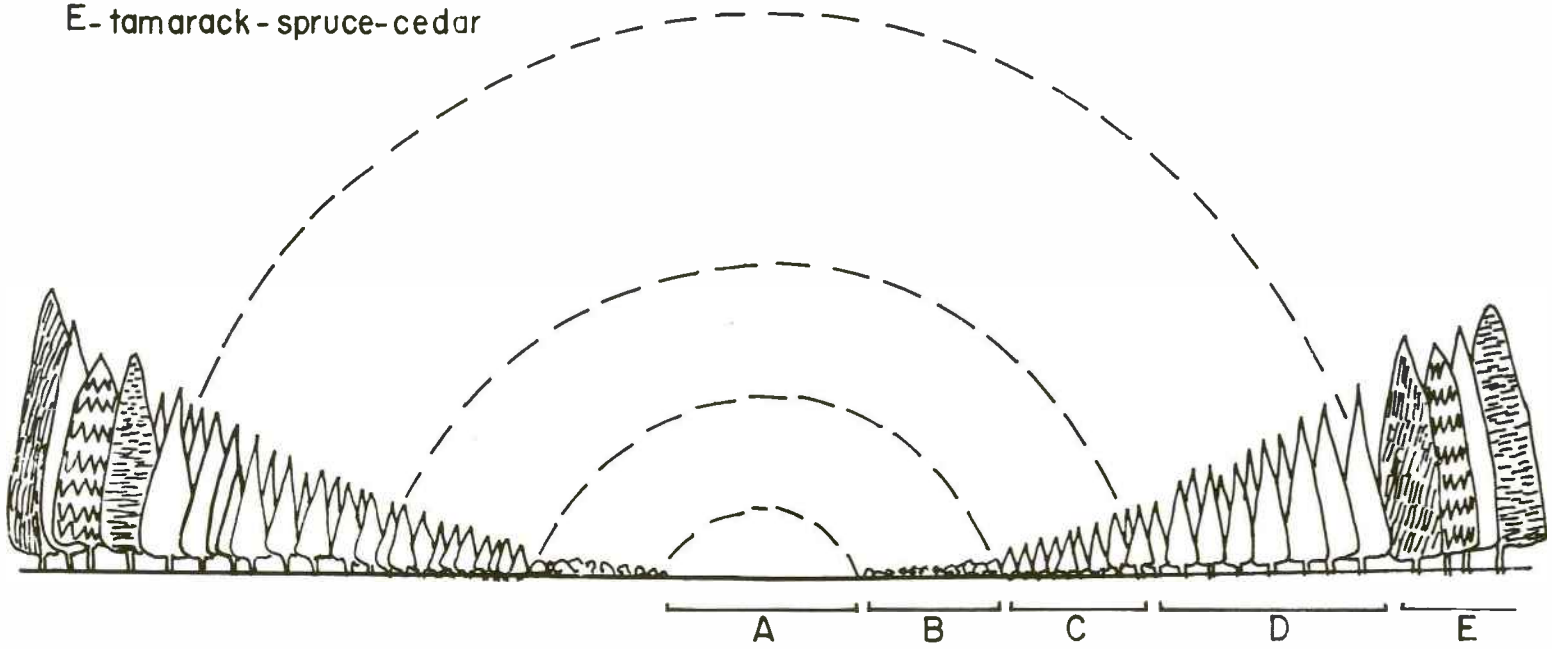


FIGURE 1

Aerial reconnaissance overcomes problems of inaccessibility and permits on-the-spot mapping of terrain for which satisfactory maps are not already available. With the experience gained last year, and the unique applicability of the technique where this particular problem is concerned, aerial reconnaissance activities will be continued and possibly even enlarged upon in 1950.

RELATIONSHIP OF SITE TO SAWFLY ABUNDANCE

As mentioned in the preceding section, ground surveys in particular are complicated by variability of site on which tamarack is found. Reference is made to Figure 1, which depicts, in the form of a diagram, the various levels of site adequacy. Zones "A" and "B" are not favorable to the establishment of tamarack, and although establishment may take place in "C", growth is poor. Whether or not low incidence of attack on trees in this zone is due to (1) poor leader growth inadequate for oviposition, or (2) high water level detrimental to overwintering pre-pupae, or some other cause or combination of causes, cannot be determined at this stage of our knowledge. Poor leader growth as a factor, whatever its cause, is best reconciled with observational evidence. By way of elaboration, it can be pointed out that demarcation of the defoliated area, where zonation is typical, frequently is quite distinct. In other words, the transitional area of defoliation between "D" and "C" is not very broad, suggesting that (1) either ovipositing females do not move far from where they had cocooned, or (2) establishment of adults moving from "D" to "C" is restricted by some factor or factors which are unfavorable at "C". This might well be leader growth. Even when defoliation is 100 percent in "D" the transitional area is still smaller than would be expected if the ovipositing females were to distribute themselves in accordance with availability of larval food. Since even unthrifty trees have foliage suitable for feeding, it must be assumed that scarcity of egg laying sites is an important deterrent, whether such be due to inadequacy of shoots for oviposition or whether maximum growth takes place after maximum adult emergence. Previous workers have stressed environmental reactions which affect the insect directly, e. g. cocoon submergence, as being responsible for the "escape" of some stands. This is undoubtedly true in many cases, but it offers a too convenient explanation of what shapes up as an infinitely more complex problem.

In addition to the typical zonation already cited, anomalous situations exist which apparently do not conform to this pattern. These can be grouped into a second category although they may be dissimilar in certain important respects. Most of the small, uniformly infested stands fit into this group. Many of these exhibit a relative unconformity between "A" and "D", so that the spatial relation is over-emphasized while the temporal relation is obscured. Since no gradual shallowing of the water occurs, zones "B" and "C" are lacking, and when this type of area cannot be viewed as an entity, its real nature is difficult to ascertain. "Escape" zones "B" and "C" being absent, the observer sees a homogeneous infestation. Factors which complicate this picture are (1) abnormally high water levels for short periods and (2) local irregularities of terrain, either or both of which act directly to influence tree vigor and/or establishment of competitive tree species.

A third situation frequently encountered exists because encroachment of "D" has resulted in elimination of zones "A", "B", and "C". An infestation of this type of stand can be homogeneous. On the other hand, the predator population is also apt to be larger as a consequence of a lower water table and a more diversified flora in all or parts of the stand. The influence of rodents in this situation may be considerable, so that little defoliation takes place under what appear to be excellent conditions for cocoon survival and adult oviposition.

The foregoing is an attempt to initiate a set of standards by which susceptibility of a tamarack stand to attack may be judged. If it is assumed that there are no differences in susceptibility, and permanent observation plots are set up accordingly, erratic results are inevitable. Even though the foregoing approach may prove inaccurate, and it certainly is incomplete, nevertheless it provides a working hypothesis and makes possible a more intelligent approach to surveys.

From the standpoint of trying to type the various stands encountered during a ground survey, presence and abundance of specific plants would appear to offer the best hope of recognition. In accordance with this idea a start was made in 1949 towards cataloguing plants in a number of study areas. More quantitative studies, using community structure as the indicator, will be attempted this season. At the present time, only a description of vegetation within each of the areas is available with which to test the utility of this approach. If results of additional study demonstrate that a correlation exists between capacity for sawfly build-up in a particular bog and the plant community present, local variations encountered in sampling should be more easily understood.

The following Table I lists six areas which were visited as frequently as other duties permitted in 1949. Each one is accompanied by observations on stand composition, maximum defoliation last year, nature of ground cover - with an estimate of prevalence for each, and a brief description of the terrain and average DBH of tamarack in the stand. Finally, under the column "Probable Nature of Stand", an effort is made to place the site in its proper zone (Figure 1).

TABLE I.

DESCRIPTION OF STUDY AREAS

LOCATION	STAND COMPOSITION	TAMARACK PER-CENT	TAMARACK AVERAGE DBH	TAMARACK RANGE	AVERAGE DEFOLIATION 1949 (Percent)	GROUND COVER	PER-CENT	TERRAIN	PROBABLE NATURE OF SWAMP
T 144 N - R 31 W - Sec. 5	Cedar Tamarack Other	75 20 5	5.0"	2" - 8"	50	Sphagnum Grasses Woody Plants	50 45 5	Rough, pot-holes present; areas of treeless swamp	Zone "E"
T 146 N - R 29 W - Sec. 28	Tamarack Other	99 1	4.5"	1" - 8"	10	Sphagnum Woody Plants	90 10	Level	Zone "D"; "A", "B" and "C" eliminated by encroachment of "D"
T 146 N - R 31 W - Sec. 30	Tamarack Other	98 2	3.5"	2" - 6"	100	Sphagnum Woody Plants Grasses	50 30 20	Rough; pot-holes present.	Unconformity
T 145 N - R 31 W- Sec. 27	Tamarack Bl. Spruce Balsam Cedar	75 20 5	3.3"	1" - 6"	75	Sphagnum Grasses Woody Plants	50 45 5	Moderately rough	Unconformity
T 145 N - R 28 W - Sec. 27	Tamarack Other	99 1	5.5"	3" - 8"	1	Sphagnum Grasses Woody Plants	50 10 40	Very rough	Zone "D"; probably "A", "B" and "C" eliminated by encroachment of "D"
R 145 N - R 29 W Sec. 21	Tamarack Others	98 2	5.0"	2" - 8"	100	Grasses Sphagnum Woody Plants	50 30 20	Rough	Zone "D". All zones but "C" present

PARASITE REARING

Included in the survey report already mentioned is a summary of cocoon collection data, along with an analysis of these data as a possible indicator of populations present. The primary purpose of these collections was to get some picture of the extent to which natural controls are operative at the present time. Cocoons were handled in a manner suggested by L. O. Kenteith of the Dominion Parasite Laboratory, Belleville, Ontario.

Prior to the start of rearing the cocoons were packed in sphagnum and stored in a refrigerator at a temperature several degrees above freezing. The sphagnum was moistened periodically. In a large number of cases, 400 cocoons were available for rearing from each collecting point and these were ultimately placed in small vials approximately 3" deep by 3/4" in diameter; 20 cocoons to the vial. A number of the State contributed samples were too small to reflect parasite abundance, and are omitted here. A 3" strip of absorbent paper was placed in the vial and the open end closed with fine wire strainer cloth held by a rubber band. By handling the vials in such a manner, it was thought that mortality due to parasitic fungi and to a lesser extent hyperparasitic insects would be minimized. The top of each tray of vials was first covered with moistened germinating paper, but since this seemed to promote growth of fungi, this method was abandoned in favor of squirting a fine stream of fresh water into the vials at 48 - 72 hour intervals. Using this method, it was possible to replenish the moisture periodically and it was felt that fungus growth did not constitute as much of a problem. Parasites and adults were removed from the vials as they emerged, and despite the fact that some live prepupae remained in early March, all cocoons were dissected and the results recorded. In this way it was possible to establish the cause of non-emergence. Also, through dissection, the presence of non-emerged adults or parasites could be recognized.

Rearing was accomplished in a constant temperature and humidity chamber in the Division of Entomology at the University of Minnesota. Hygrothermograph records for the rearing period indicate that temperature was relatively constant at 73° F. ± 3°, and the humidity was approximately 65 percent ± 5 percent.

Table II summarizes the data compiled from these rearings. The points at which samplings were made are plotted on Figure 2. Detailed tabulations of these rearings may be found in Appendix Table I.

TABLE II.

SUMMARY OF PARASITISM STUDIES

Map No.	Total No. Larvae Alive	Parasitized (Percent)			
		Bessa	Mesoleius	Tritneptis	Total
1	26	4	0	42	46
2	124	0	0	35	35
3	241	17	-1	50	68
4	341	-1	-1	33	35
5	308	0	0	33	33
6	252	-1	-1	37	39
7	320	0	3	26	29
8*					
9	361	-1	0	37	38
10	385	4	6	35	45
11	316	8	4	36	48
12*					
13	272	-1	0	31	32
14	844	-1	1	77	79
15	304	13	3	34	50
16	247	-1	0	64	65
17	256	9	0	39	48
18	275	3	1	33	37
19	258	0	2	68	70
20	291	2	16	30	48
21	313	-1	1	32	34
22	52	1	-1	43	45
23	28	14	3	7	24
24	31	10	0	30	40
25	349	2	2	44	48
26	300	5	3	52	60
27	283	-1	-1	37	39
28	202	1	4	42	47
29	47	0	0	60	60
30	12	0	0	36	36

* Nos. 8 and 12 - 100 percent cocoon mortality.

The foregoing table gives a breakdown of parasitism from 28 cocoon collection points in Minnesota (Figure 2). Collection points 8 and 12 were rejected because of complete mortality due to fungi which occurred in rearing. Figures are given for parasitism by Bessa harveyi T. T., Mesoleius sulicus Grav. and Tritneptis klugii Ratz. respectively, using as a basis only those cocoons which were not killed by fungi or known to be adversely affected by handling. The highest figures shown for Bessa harveyi are 17, 14, 13 and 10 percent, and for Mesoleius sulicus in only one case was the parasitism higher than 10 percent. Parasitism by Tritneptis klugii appears to be quite high in general. There is some doubt, however, as to how much of this is due to hyperparasitism. The tendency of this species to parasitize a fresh cocoon after having just emerged from another one is well known. It was thought that segregation of each series into a number of lots of 20 per vial would tend to minimize hyperparasitism, but it seems possible that any of the 20 cocoons in each vial could have been parasitized by Tritneptis emerging from one in which they had overwintered. The problem of obtaining quantitative figures on parasitism - based on large numbers of cocoons - is complicated not a little by this tendency. Some modification of the technique will have to be used for rearings made in 1950.

The figures do indicate the presence of the three species in Minnesota, and the experience gained in these rearings should prove useful in the conduct of similar operations this year. Also recovered in addition to the above species were several specimens tentatively identified as Cryptus canadensis Prov. and Laberychus analis Say.

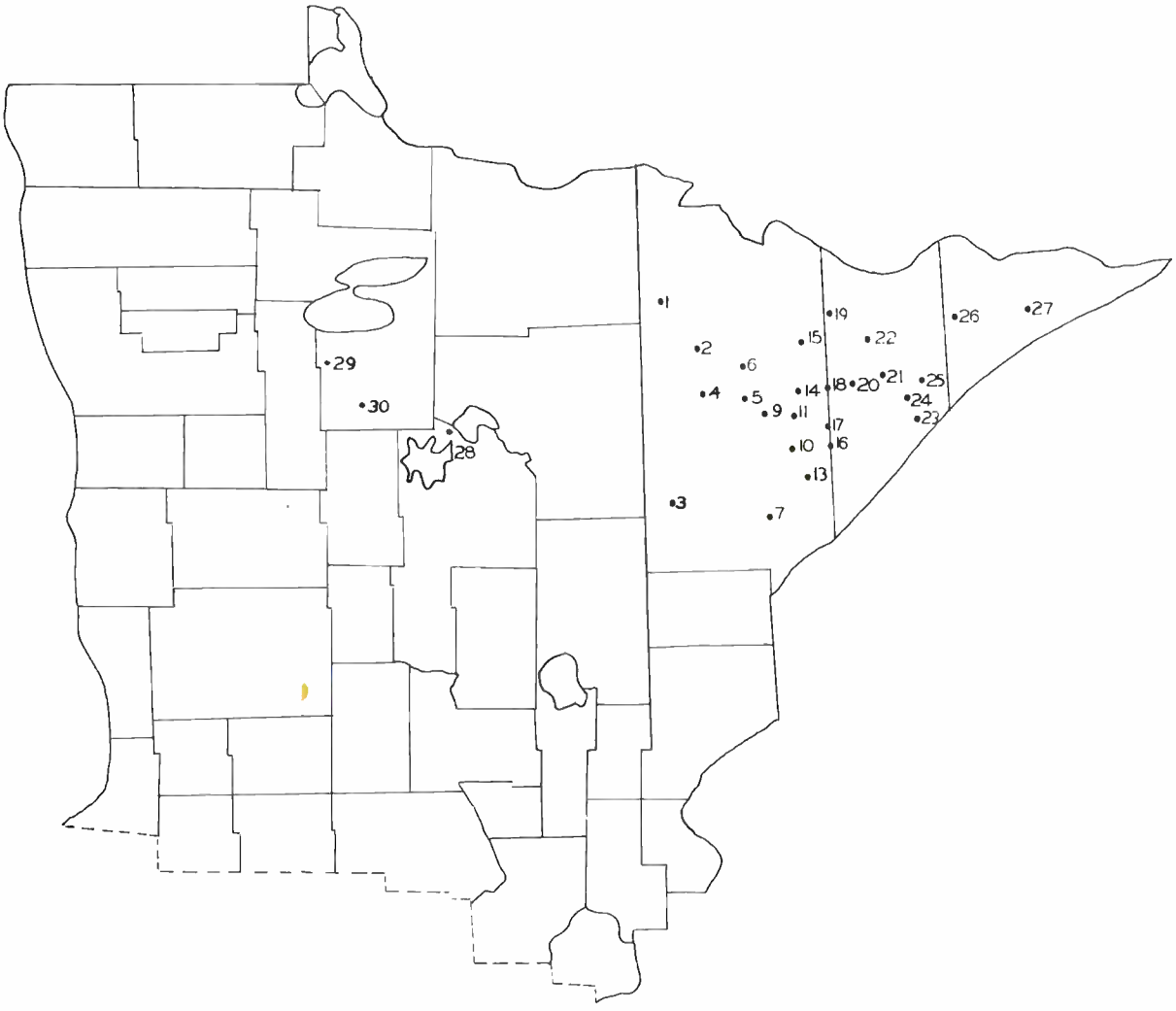
EXPERIMENTAL CONTROL WORK

One of the primary objectives of the larch sawfly work in 1949 was an evaluation of aerial spraying for control of this insect. It was in this respect that late arrival in the field was most keenly felt. Despite heavy defoliation throughout the Chippewa, it was difficult to find federal holdings of sufficient size to make aerial applications practicable. Much of the first two weeks on the Forest was spent in trying to find such sites. Finally, on July 11, arrangements were completed for spraying 80 acres of tamarack in the Birch Hill Tower area of the Cass Lake District. On the evening of July 12 the spray was applied by the Montgomery Airspray Company, Grand Forks, N. D. The equipment used in this operation was a Stearman employing a boom under the lower wing containing 14 nozzles; 7 on each wing. The 2 nozzles adjacent to the fusilage had 1/16-inch openings, the next two 3/32-inch openings, with the last three on each wing having 1/8-inch openings. At a pressure of 80 pounds per square inch, the delivery rate was 15 gallons per minute. The flight was made at an altitude of 80 - 90 feet, on an average of 10 - 15 feet above the tree tops. Wind was not more than 7 miles per hour at any time during the operation.

The area sprayed was a pure tamarack stand with an average DBH of 4.5 inches, and an average estimated defoliation of 20 percent. Since it was not possible to sample extensively before spraying, a control was set up in a confluent stand of tamarack to the north of the treated area.

FIGURE 2

COCOON COLLECTION POINTS



Although some cocooning had taken place prior to spraying, high water levels, due to heavy rains, raised the possibility that many of those larvae dropping to the ground might not survive. The following figures give some idea of the percent of crown under water, as well as an insight into the nature of the area itself:

TABLE III.

CHARACTERISTICS OF SPRAYED AREA

Tree No.	Crown Length (Feet)	Crown Width (Feet)	D.B.H. (Inches)	Defoliation (Percent)	Amount of Crown Area Under Water (Percent)
1	20	6	4	20	65
2	20	8	5	20	40
3	30	8	4	20	70
4	25	8	4	25	30
5	35	10	4	30	60
6	30	15	6	15	15
7	15	8	5	20	48
8	12	10	5	25	55
9	30	10	5	10	60
10	15	6	3	10	40
Average	23.2	8.9	4.5	19.5	48.3

The following sampling methods were used in the sprayed and to a lesser extent, the unsprayed areas:

1. Frass Collections - employing square foot sheets of manila paper treated for adhesion with a Tanglefoot preparation.

2. Square Foot Soil Samples - counting cocoons to a depth of 4 inches.

3. Square Foot Samples of Larvae in the Pools.

4. Drop Cloths - to determine larval drop due to spraying.

5. Jarring Trees - using a 15 pound club and collecting dislodged larvae in a standardized drop cloth.

EVALUATION OF SAMPLING RESULTS:

For frass sampling, square foot sheets of brown paper treated with Tanglefoot were placed under 5 different trees in both the sprayed and unsprayed areas and examined at 48- and 72-hour intervals subsequent to spraying. Since the season was relatively advanced, frass production

by first, second, and third instar larvae was negligible, and only fourth and fifth instars were present in sufficient numbers to enter into the calaculations. The following Table IV illustrates decline in frass production in both the sprayed and the unsprayed areas over a 9-day period:

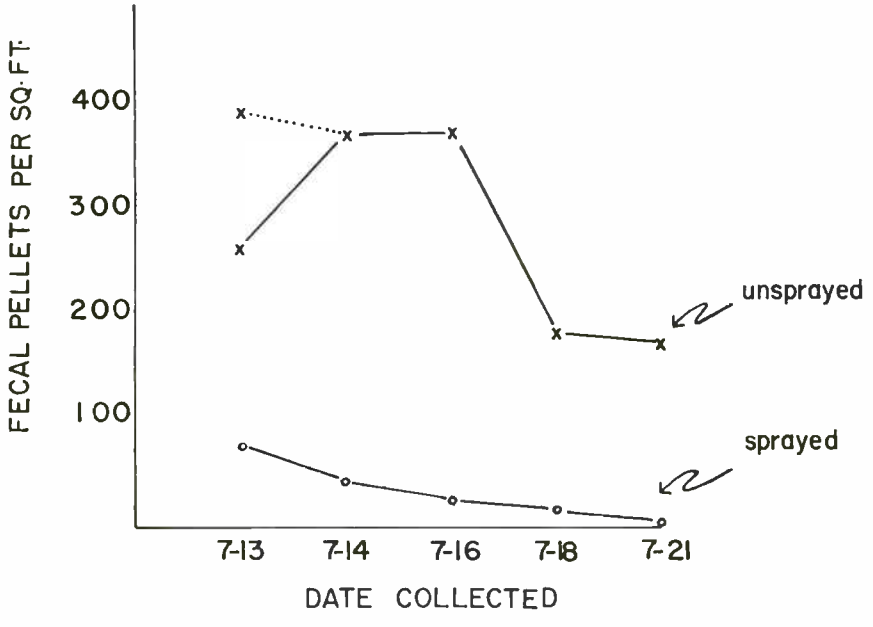
TABLE IV.

SQUARE FOOT FRASS SAMPLINGS - 24 HOUR PERIODS

Date Coll.	Instar	FECAL PELLETS PER SQUARE FOOT — Sprayed — Sheets 1	2	3	4	5	Average	Unsprayed — Sheets 1	2	3	4	5	Average
7/13	4th	24	44	12	12	16	21.6	96	96	122	16	92	84.4
	5th	40	68	52	164	68	78.4	280	336	240	144	332	266.4
7/14	4th	8	4	12	56	0	16.0	97	112	48	48	50	71.0
	5th	12	32	20	120	24	41.6	304	608	266	212	480	374.0
7/16	4th	6	2	6	8	2	4.8	104	79	34	71	64	70.4
	5th	19	26	24	52	22	28.6	291	736	259	196	416	379.6
7/18	4th	4	4	16	0	4	5.6	12	39	15	24	25	23.0
	5th	4	12	10	24	11	12.2	132	340	119	68	248	181.4
7/21	4th	1	0	0	0	0	0.2	34	48	14	10	16	24.4
	5th	1	1	3	4	0	1.8	167	382	64	41	202	171.2

It should be noted that the above counts are for 24-hour periods irrespective of when the sheets were collected. For example, the 7/16 figure represented a 48-hour accumulation, but was divided by two to make the comparison more valid, thus the figure is a daily average for the 2-day period. The decline of frass production in the sprayed area is much better appreciated from an analysis of the following curves (Figure 3), showing fifth instar fecal pellets per square foot over the 9-day period. Here again, the lower position of the curve for the sprayed area tends to give an erroneous picture of the population present. Since there was no opportunity to sample the areas prior to spraying, the curve for the unsprayed portion at 7/13 would be fairly representative of the population present in either one before spraying took place. The 7/13 figures represent frass accumulation of untreated larvae for a 16-hour period in the unsprayed and only an 8-hour period in the sprayed area. The fact that the 7/13 figure represents a 16-hour instead of a 24-hour collection accounts for the apparent increase which took place between the 7/14 and 7/16 figures in the unsprayed area. The dotted line shows this figure equated to a 24-hour period. Actually, the drop in the curve for the control at 7/16 agrees very well with frass decline in other study plots. It seems reasonable to assume that this was the peak of cocooning, and even if it is considered that this contributed to the decline exhibited by the curve for the sprayed area, the effects of the spraying are quite striking. It would

FIGURE 3


FECAL PELLETS PER SQ. FT.
400
300
200
100
unsprayed
sprayed
7-13
7-14
7-16
7-18
7-21
DATE COLLECTED

not be illogical to attribute the persistent decline in the latter case to a residual effect of the spray, since a comparable period for the control area did not show a similar tendency.

An apparent correlation was found to exist between frass production and degree of control indicated by the other sampling methods used to evaluate the effects of spraying. Table V gives figures obtained from making counts of larvae on the ground (16 hours after spraying) which showed DDT tremors. None were observed in the unsprayed control (not shown), whereas an average of 5.6 per square foot were noted in 10 counts in the treated area. Table VI gives counts of larvae in ground pools - figures on a square foot basis. Since larvae falling into water invariably drown (see Photograph "D") it was felt that this would give a fair picture of the number coming down. It can be noted that there were over twice as many larvae per square foot in pools under the sprayed trees as there were in the control. Table VII gives figures on drop cloth collections; an average of 10.7 larvae per 2' x 4' drop cloth 8 hours after spraying.

TABLE V.

NUMBER OF LARVAE PER SQUARE FOOT SHOWING DDT TREMORS
(16 HOURS AFTER SPRAYING)

TREE NO.	INSTAR 1	2	3	4	5	TOTAL LARVAE
1	0	0	0	0	8	8
2	0	0	1	0	5	6
3	0	0	0	1	8	9
4	0	0	0	1	4	5
5	0	0	0	1	4	5
6	0	0	1	0	10	11
7	0	0	0	0	5	5
8	0	0	0	0	5	5
9	0	0	0	0	2	2
10	0	0	0	0	0	0
TOTAL	0	0	2	3	51	56
AVERAGE	0	0	0.2	0.3	5.1	5.6

TABLE VI.

COUNT OF NUMBER DROWNED LARVAE PER SQUARE FOOT GROUND POOLS

TREE NO.	TREATED		CHECK	
	7 - 13	7 - 21	7 - 13	7 - 21
1	21	25	5	2
2	19	38	3	5
3	15	20	10	12
4	18	26	7	8
5	24	9	8	5
6	15	34	3	2
7	8	27	9	3
8	17	32	10	4
9	8	21	3	12
10	9	11	2	7
TOTAL	154	243	60	60
AVERAGE	15.4	24.3*	6.0	6.0*

* Difference between 7 - 21 check and sprayed means is highly significant.
t = 9.8 1 percent level = 2.875

TABLE VII.

COUNTS OF LARVAE ON 2' x 4' DROP CLOTHS 8 HOURS AFTER SPRAYING - (SPRAYED AREA)

TREE NO.	INSTAR					TOTAL LARVAE
	1	2	3	4	5	
1	0	0	0	1	3	4
2	0	0	1	6	31	38
3	0	0	0	1	5	6
4	0	0	0	0	9	9
5	0	3	10	0	18	31
6	0	0	0	0	13	13
7	0	0	0	2	3	5
8	0	0	0	1	0	1
9	0	0	0	0	0	0
10	0	0	0	0	0	0
TOTAL	0	3	11	11	82	107
AVERAGE	0	0.3	1.1	1.1	8.2	10.7

Photograph "D"

Drowned mature larch sawfly larvae visible in shallow portion of ground pool (left center). (Chippewa National Forest - 1949).

In Table VIII are given figures for square foot soil counts of cocoons. It should be noted that at this time (16 hours after spraying) the counts were very close in both areas, indicating that some cocooning had taken place but not very much. Similar samplings made on July 21; 9 days after spraying, show that over 3 times as many cocoons were found per square foot in the unsprayed as in the sprayed area. Samplings of ground pools this same date disclosed 4 times as many larvae present in the sprayed as in the unsprayed (Table VI). Table IX is a record of larvae collected on 2' x 4' drop cloths when individual trees were jarred by striking with a 15 pound club. On July 14, 40 hours after spraying, 10 larvae were dislodged per tree as compared to .6 per tree on July 18.

TABLE VIII.

NUMBER OF COCOONS PER SQUARE FOOT OF SUB-SOIL

TREE NO.	TREATED		CHECK	
	7 - 13	7 - 21	7 - 13	7 - 21
1	2	0	3	5
2	2	2	6	15
3	4	2	4	7
4	5	5	5	19
5	7	1	9	11
6	4	6	11	4
7	6	0	3	2
8	2	4	2	16
9	8	8	6	16
10	4	1	4	7
TOTAL	44	29	53	102
AVERAGE	4.4	2.9*	5.3	10.2*

* Percent increase in check 92 percent. Difference between 7 - 21 check and sprayed means highly significant.
t = 3.50
1 percent level = 2.875

TABLE IX.

NUMBER OF LARVAE COLLECTED ON 8 SQUARE FOOT DROP CLOTHS AFTER JARRING THE TREES

TREE NUMBER	TREATED		CHECK	
	7 - 14	7 - 18	7 - 14	7 - 18
1	5	0		5
2	0	0	N	14
3	5	0	O	19
4	0	1	T	14
5	1	0		2
6	21	0	S	22
7	1	0	A	8
8	21	1	M	17
9	20	0	P	36
10	26	4	L	11
			E	
TOTAL	100	6	D	151
AVERAGE	10.0	0.6*		15.1*

* Percent decrease in sprayed 94 percent. Difference between 7 - 18 means of check and sprayed highly significant.
t = 15.1 1 percent level = 2.875

On July 18 in the control, however, an average of 11 larvae per tree were dislodged, indicating that there were still some larvae present in the trees. These data are borne out by the frass collection curves in Figure 3 which, while showing a sharp decline from the 7/16 position, still indicate that some feeding was taking place.

Slope of the curves in Figure 3 suggest that the populations present in the treated area after July 13 might have been adversely affected by spray residues. Figures on cocoon counts made July 21 would appear to offer some evidence that very little, if any, cocooning took place in the treated area after the July 13 counts had been made. The apparent decrease in cocoons per square foot between the July 13 and July 21 samplings in this case is probably due to experimental error since there was little rodent activity in these swamps at that time.

From the foregoing data and discussion it is apparent that the application of DDT was responsible for considerable mortality of the larval populations present in the treated areas. It is felt that better results might have been obtained had the spraying taken place earlier. The problem of effectively controlling this species with one application may not be resolved by variations in time of spraying alone, since the biology of the insect is such that it is virtually impossible to spray

at a time when only the larval stage is present. Conclusions as to whether or not timing of applications to hit the peak of larval abundance is the answer must await the results of further experimental work.

PROPOSED PARASITE RELEASE

This office has been in touch with A. B. Baird, Chief of the Biological Control Investigations Unit, Ottawa, Canada with reference to procuring several colonies of Mesoleius sulicus for release in selected areas in Minnesota. Permits to cover shipment of these parasites have been furnished by C. P. Clausen (Principal Entomologist, In Charge Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine). Alfred Wilkes, Officer in Charge Dominion Parasite Laboratory, Belleville, Ontario, will forward this material to the Cass Lake Field Station at a mutually acceptable time. These colonies will be liberated in several areas to be selected on the basis of populations present this year and whether or not the parasite was present in 1949.

In addition, mass liberations of Tritneptis will be attempted, depending on the supply available - from cultures on hand at University Farm, Minnesota. An effort will be made to restrict liberations to areas where Mesoleius and Bessa did not show up in last year's rearings, or in one or more of the areas where parasitism by these species was lowest. A number of small areas which were heavily defoliated last year will be considered for these liberations in hopes that establishment might be more readily recognized, should it occur.

FRASS SAMPLING AND INTERPRETATION

A program of population sampling, based upon frass collections, was initiated in 1949. Three areas in the vicinity of Cass Lake were visited as often as other duties permitted. The pressure of other work, and the heavy rains made it difficult to get suitable daily collections. Nevertheless, it was feasible to obtain a record of development based upon 24-hour collections from July 6 through July 23 - in two of the study areas, as well as a partial record for a third.

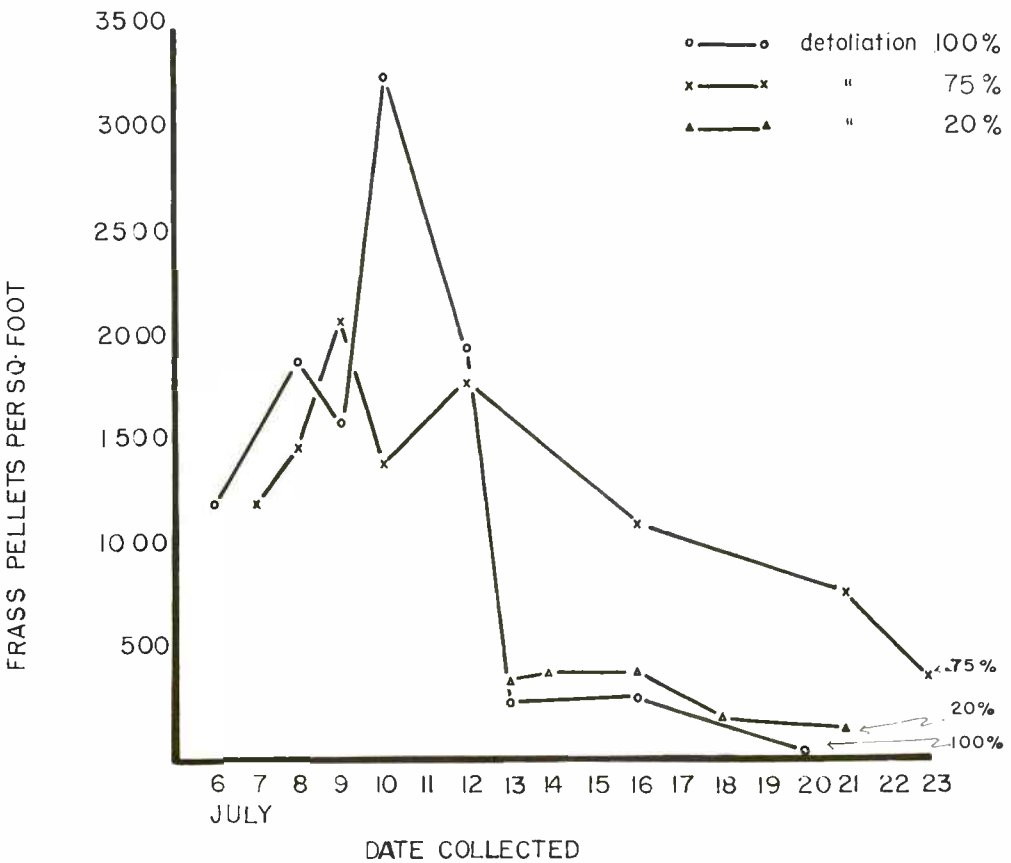
It was felt that frass sampling, if properly carried out, might yield valuable information not only on population size, but also on various aspects of the biology of the insect. There proved to be shortcomings in the methods used, however, which invalidated much of the data. The chosen procedure consisted of cutting brown manila wrapping paper into square foot sheets, after which one side of the paper was treated with an adhesive called "Stop" manufactured by the Acme White Lead and Color Works. Five of these sheets were then placed in each of the study plots, employing the same spot for each sheet throughout the course of feeding. One of the major shortcomings of this method was the tendency of the smaller fecal pellets to wash off or disintegrate during the frequent rain storms which occurred in 1949. Despite the difficulties encountered, a few interesting points are raised by those figures which are usable.

There is reason to feal, for example, that a large population which causes complete defoliation of a stand may be the means of protecting that

particular stand from heavy attack the following year. This may be true for several reasons: (1) heavy oviposition injury, making it unlikely that next year's deformed shoots can support egg colonies capable of causing severe defoliation, and (2) heavy populations may mean a premature termination of larval development due to complete exhaustion of the food supply. It was a desire to cast some light on this aspect that prompted the starvation studies begun in 1949, and which are discussed in the next section. The premature termination of feeding because of absence of food has particular significance in this case because precipitation records show that the first cessation of daily rainfall occurred on the 12th of July. On July 5th, 3.33 inches of rain fell and again on July 8th 2.46 inches were recorded for a one hour period. For the first 12 days of July, 7.34 inches of rainfall were recorded, as contrasted to a 32-year average for the month of July of 2.85 inches. This, added to the high water levels already present, resulted in some 65 percent of the ground being covered with water. If there had been abundant food for a longer period, many of the immature larvae probably would not have dropped before the water level had subsided, and their chances of survival would have been improved. Reference to Figure 4 confirms this hypothesis somewhat. Curves are presented for 3 areas; one where defoliation was 100 percent in 1949; a second where defoliation was 75 percent maximum in 1949, and a third where 1949 defoliation was only 20 percent maximum. Admittedly, these data are only suggestive, but they serve to emphasize the complexity of this problem. One cannot say, for example, that populations in the area of 75 percent defoliation would be as greatly influenced by heavy rainfall which occurred in the first 12 days of July as were the populations in the area of 100 percent defoliation. The decline in frass production in the former dropped by July 13th to a level not reached by the latter even by the 23rd of July. Since the trees in the former were completely stripped by this time, it must be assumed that the larvae had to drop to the ground regardless of their stage of development. As a matter of record, counts of larvae in ground pools in this area averaged over 100 per square foot on the 15th of July. The decline in frass production in the area of 75 percent defoliation is much more orderly, while the fragmentary record for that of 20 percent defoliation shows a decline at a still slower rate.

The technique of plotting used here suggests its application to another important line of investigation. At the present time, we are not in a position where we can say whether 100 percent defoliation where it occurs is due to (a) a population in which virtually all members are able to reach maturity at the time of exhaustion of the food supply, or (b) a population greater than the available food supply can support. When we are dealing with a tree species which can stand repeated defoliations, the effects of intra-specific competition can be of considerable importance both in predicting successive attacks and in dictating control measures. If an abrupt decline, as suggested in the curve for 100 percent defoliation is in fact evidence of premature termination of feeding because of exhaustion of food supply, then intermediate gradations toward the slope typified by the 75 percent defoliation curve might be indicative of lesser degrees of population pressure.

FIGURE 4


3500
3000
2500
2000
1500
1000
500
FRASS PELLETS PER SQ. FOOT
detoliation 100%
" 75%
" 20%
75%
20%
100%
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
JULY
DATE COLLECTED

Frass production as a criterion of absolute population can have little validity unless checked against other sampling methods. If satisfactory evidence can be accumulated to show that the characteristics of frass production curves already mentioned are reliable indicators of these or other phenomena associated with population size, such a technique may provide a yardstick in itself to which other sampling techniques can be related. Some such yardstick is sorely needed, and represents a major objective of these studies.

LABORATORY STUDIES

The problem of properly interpreting frass production as an index of population size and progress of development suggested that some work on feeding habits and the influence of physical factors might well be done under laboratory conditions. As a consequence, laboratory experiments were set up rather hurriedly in order to at least perfect a rearing technique which could be used for subsequent studies. By the time this work was initiated, cocooning was already taking place in the field, so that it was not possible to replicate any of this work last year.

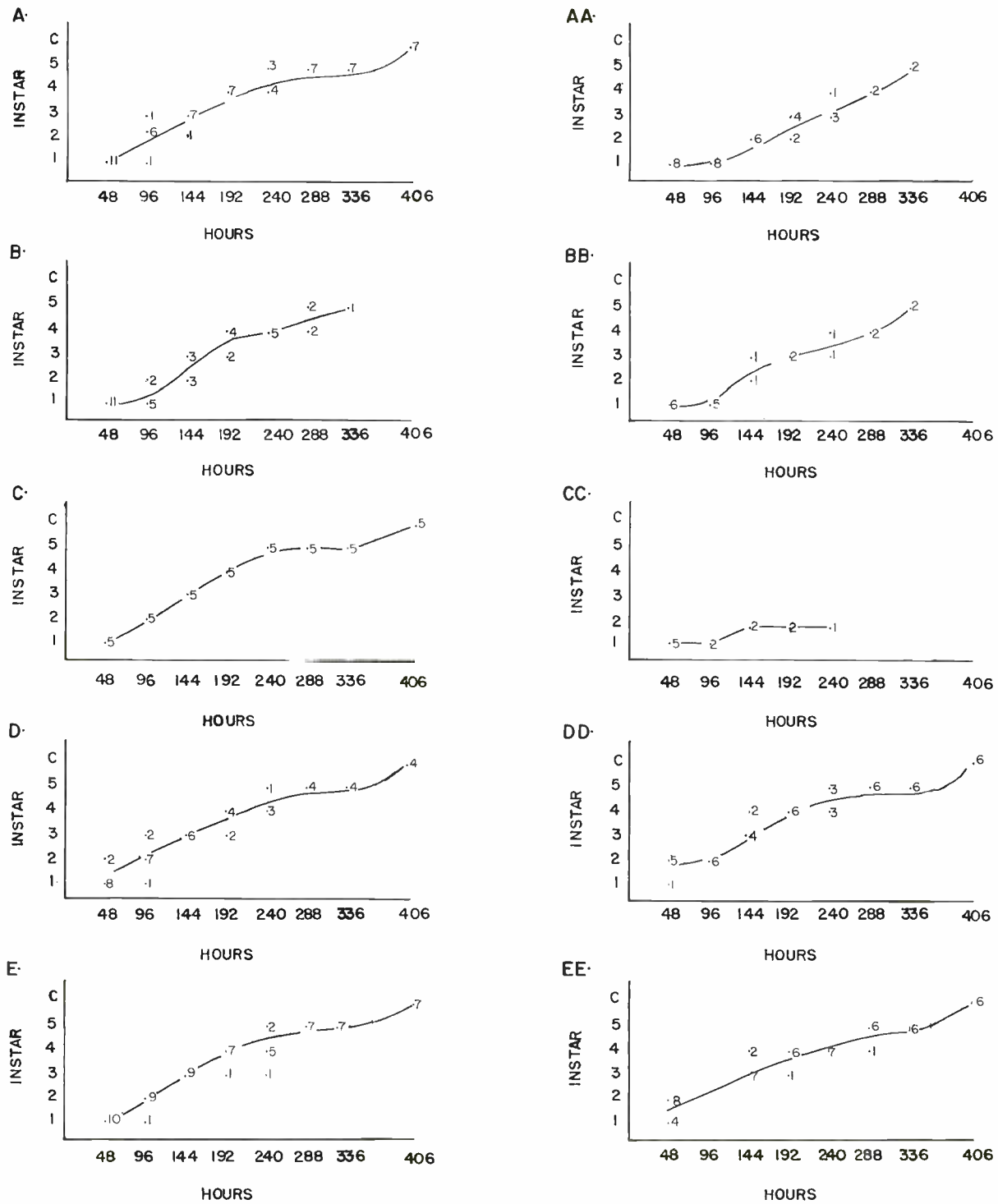
A. Effect of physical factors on larval development

A series of experiments were devised wherein newly hatched first instar larvae were placed on fresh larch sprigs which were changed daily, the larvae being transferred to the fresh material with a camel's hair brush. This undoubtedly accounted for much of the mortality in the first instar. Conditions for these experiments were as follows:

	Number of Larvae	Temperature Average Max. 78° Average Min. 56°	Light
A	20	Outdoors	24 hours
B	20	"	12 "
C	20	"	None
D	20	"	A. M.
E	20	"	Afternoon
AA	20	Basement - 63° F ± 3°	24 hours
BB	20	" 63° F ± 3°	12 "
CC	20	" 63° F ± 3°	None
DD	20	" 63° F ± 3°	A. M.
EE	20	" 63° F ± 3°	Afternoon

All of these preliminary experiments were run in the insectary and at no time was direct sunlight available to any of the larvae. Artificial light from a 100 watt bulb 4 - 5 feet from the feeding insects was the only source of light for those held in the basement. That light in itself was not an important factor in either development or survival is suggested by the D and E series on Figure 5. Plotted on the vertical axis are instars (1 - 5) and the cocoon stage (C), while on the horizontal axis is the duration of development in hours. The number of survivors and their stage of development can be read from the figures along the curves.

FIGURE 5



Development curves for light-temperature studies

Groups "D" and "DD" were subjected to natural and artificial light respectively for 6 hours in the morning and groups "E" and "EE" to natural and artificial light respectively in the afternoon. Development is at a slightly slower rate in both groups "DD" and "EE", but this is also true for all those larvae held at the lower temperatures. The very poor survival in group "CC" as contrasted to group "C" suggests that complete darkness may be deleterious at the lower temperature, however. The high mortality in all cases makes it imperative that the technique be modified; and these data have no value except insofar as they suggest lines of investigation in 1950.

B. Effect of starvation on larval survival

Preliminary work on starvation of larvae was attempted to throw light on (1) the ability of fifth instar larvae to cocoon when the food supply is inadequate (such as occurs frequently where defoliation is 100 percent); (2) the length of time larvae of each instar can survive without food in the event they are dislodged from the trees by wind or rain or must migrate in search of food; and (3) the possible relationship of food shortage to fecundity or egg production of adults.

The technique in this case was to insert a twig of larch in a small bottle of water and place newly molted fifth instar larvae which had been starved for various periods (column D, Table X) on the needles. Some of the larvae managed to crawl through the protective cover between the foliage and water and were drowned. While these experiments themselves are only preliminary to further work, they are inserted here for the record. In Series II, the controls "c", "d", and "e" show a higher percentage survival than do those starved for 14 hours prior to feeding. Since such small numbers were used, any question of significance of any of these figures is purely academic. The information will be used for further work along these lines in 1950.

TABLE X.

STARVATION EXPERIMENT DATA

		A	B	C	D	E	F		G	H	
		Fed Before Starving (Hrs.)	Starvation Temperature	Feeding Temperature	Hours Starved	Larvae at Start	Natural Mortality Number	Percent	Drowned	Cocooned Number	Percent
I	a	24	Outdoors	Outdoors	12	9	4	57	2	3	43
	b	24	"	"	24	8	4	57	1	3	43
	c	-	"	"	-	10	7	70	0	3	30
	d	-	"	"	-	10	7	70	0	3	30
II	a		61°	61°	14	12	8	67	0	4	33
	b		54°	54°	14	12	8	67	0	4	33
	c		-	Outdoors	0	10	1	10	0	9	90
	d		-	54°	0	10	0	0	3	7	100
	e		-	61°	0	10	0	0	4	6	100
	f		Outdoors	Outdoors	14	10	7	86	2	1	14
III	a		Outdoors	Outdoors	24	10	5	64	2	3	37
	b		"	"	24	12	5	50	2	5	50
	c		"	"	0	8	2	25	0	6	75
	d		"	"	0	10	4	40	0	6	60
	e		"	"	0	9	0	0	1	8	100
	f		"	"	24	10	5	50	0	5	50

MISCELLANEOUS ACTIVITIES

Since the summer of 1949 was the first time the Cass Lake field station had been active for a number of years, a good part of the first week in residence was spent in getting the facilities into service. Contacts incident to locating possible spray sites and service calls dealing with other insect problems of Forest Service districts on the Chippewa were also carried out throughout the summer. Subsequently, similar work was carried out on the Superior National Forest and with St. Louis County officials at Duluth.

A number of projects were initiated last year which will be followed up this summer. Among these are the following:

Cocoon Caches

(a) 100 cocoons were cached in each of 4 study areas of quite different composition as regards tree species and relative abundance of each, topography, and soil types. These were cached 20 cocoons per 36 square inches and are suitably marked.

(b) 1,600 cocoons were cached in 6"x6"x12" wire screen cages in a moderately wet swamp 5 miles south of Cass Lake. These were placed 400 cocoons to a cage and buried in soil so that their distribution in space approximates natural distribution in the field. These will be visited daily this spring in order to determine time of adult emergence and the size of the hold-over brood. Four hundred cocoons were similarly cached at the insectary on Swede Hill.

Wells

Five wells were dug in study areas established last year. These will be revisited in 1950, and a daily record of water level maintained and correlated with percent of cocooning universe under water. Water levels can be read directly from calibrated measuring sticks already present in these areas.

Bark Beetle Studies

Selected concentrations of tamarack were girdled in a 100 percent defoliated study area last year, and one in which defoliation was less than 5 percent. This will be followed up to determine to what extent establishment of an infestation has taken place and the characteristics of the infestation pattern in each case.

Cocoon Collections

Approximately 5,000 cocoons were collected over and above those used for parasite survey. These are present at

Cocoon Collections (continued)

University Farm under refrigeration and will be used for a number of experimental problems, among which is a cooperative study of Mesoleius development being carried out as part of a request for information by R. R. Lejeune of the Dominion Forest Insect Laboratory, Winnipeg.

REFERENCES

Butcher, James W. and Charles B. Eaton. 1950. Survey of the Larch Sawfly in the Lake States - 1949. Forest Insect Laboratory, Milwaukee, Wisconsin

Hodson, A. C., and C. M. Christensen. 1947. Minnesota Forest Insect and Disease Survey for 1946 and 1947. Paper No. 634, Misc. Jour. Series, Minnesota Agr. Exp. Sta., St. Paul, Minnesota.

APPENDIX - TABLE I.

DETAILED BREAKDOWN OF PARASITISM AS OBTAINED FROM REARINGS AND DISSECTIONS

MAP NO.	LOCATION T.	LOCATION R.	LOCATION SEC.	TOTAL COCOONS	PARASITES Bessa No.	Bessa Percent	Mesoleius No.	Mesoleius Percent	Tritneptis No.	Tritneptis Percent	LARCH SAWFLY Alive No.	Alive Percent	Dead No.	Dead Percent	Emerged No.	Emerged Percent
1	61N	20W	13	39	1	2	0	0	11	30	14	36	13	32	0	0
2	62N	18W	3	175	0	0	0	0	44	25	33	19	51	29	47	27
3	52N	18W	22	400	41	10	1	-1	120	30	31	8	159	40	48	12
4	60N	17W	22	400	2	-1	2	-1	112	28	116	29	59	15	109	27
5	60N	15W	14	400	0	0	0	0	100	25	64	16	92	23	144	36
6	61N	15W	4	400	1	-1	1	-1	92	23	64	16	150	38	92	23
7	52N	14W	29	400	0	0	9	2	84	21	115	29	80	20	112	28
8*																
9	59N	14W	22	400	2	-1	0	0	133	33	169	42	39	10	57	14
10	57N	13W	32	400	16	4	24	6	136	34	124	31	15	4	85	21
11	58N	13W	21	400	24	6	13	3	112	28	148	37	83	21	20	5
12*																
13	55N	12W	5	400	1	-1	0	0	84	21	120	30	128	32	67	17
14	59N	12W	8	400	1	-1	3	1	264	65	3	1	56	14	73	18
15	56N	11W	24	400	38	10	8	2	102	25	120	30	96	24	36	9
16	57N	11W	21	400	1	-1	0	0	159	40	43	11	153	38	44	11
17	58N	11W	25	400	24	6	0	0	100	25	80	20	144	36	52	13
18	60N	11W	17	400	9	2	2	-1	92	23	132	33	125	31	40	10
19	63N	11W	15	400	0	0	6	1	175	44	48	11	140	35	31	8
20	59N	10W	7	400	6	1	46	12	88	22	116	29	109	27	35	9
21	59N	8W	5	400	1	-1	3	1	101	25	15	4	87	22	193	48
22	61N	8W	31	68	3	4	1	1	23	36	7	10	16	23	18	26
23	57N	7W	21	50	4	8	1	2	2	4	14	28	22	44	7	14
24	58N	6W	31	45	3	7	0	0	11	24	17	37	14	32	0	0
25	59N	6W	11	400	6	1.5	6	1.5	154	39	122	30	51	13	61	15
26	62N	4W	7	400	16	4	8	2	157	39	63	16	100	25	56	14
27	62N	1E	12	400	1	-1	2	-1	104	26	148	37	117	29	28	7
28	145N	29W	23	400	4	1	12	3	119	30	113	28	118	30	34	8
29	146N	35W	35	99	0	0	0	0	29	29	18	18	52	53	0	0
30	147N	34W	30	43	0	0	0	0	4	9	8	19	31	72	0	0

* Nos. 8 and 12 - 100 percent cocoon mortality. (Small samples - parasitized by fungi in rearing.)
\# (-1) less than 1 percent parasitism.